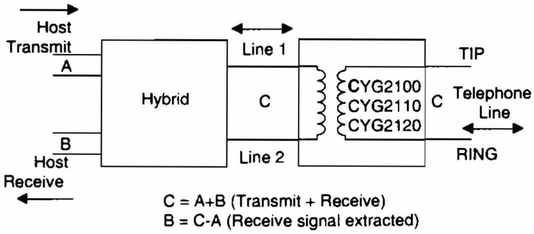


Figure 4. Two-to-Four Wire Hybrid Diagram

Referring to figure 4, the host transmit pair sends a signal denoted as 'A' to the telephone line via the CYG2000/CYG2001. Signal 'C' on LINE1/LINE2 and TIP/RING represents both the transmit signal from the host 'A' and the signal from the telephone line to the host denoted as 'B'. Signal 'C' is the sum A + B. The hybrid extracts the receive signal from the telephone line by subtracting the transmit signal from the composite signal appearing at C or B = C-A.

The practical implementation of the above scheme varies depending on the particular application, however, we will examine a very basic hybrid circuit as an example. The hybrid circuit usually consists of a dual operational amplifier and some discrete resistors as shown in figure 5. To simplify the analysis of the circuit, we will explain the operation of:

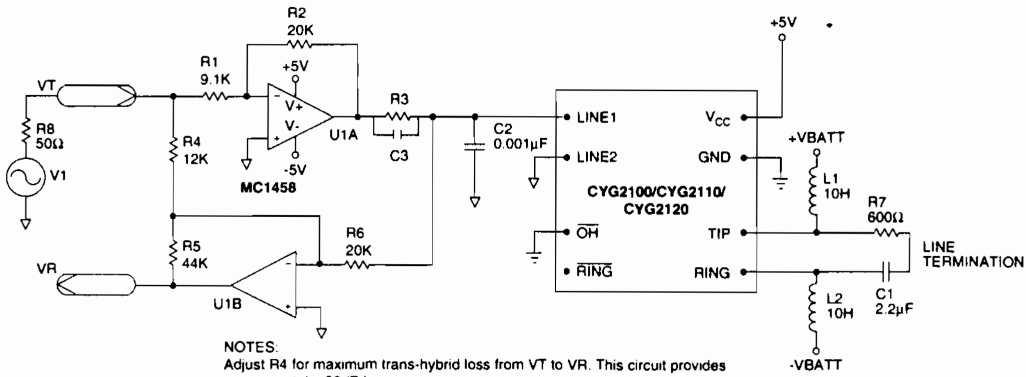
- Transmit to the telephone line
- Receive from the telephone line
- Cancellation of the host transmit signal VT from the receive path VR

Transmit to the Telephone Line

Suppose that the VT signal from the host system is at a level of -9dBm and we wish to have this signal presented to the telephone line at this level. Since the transmit insertion loss from the data sheet is specified at 7dB, it is necessary to select resistor values R2 and R1 such that U1A will amplify VT by 7dB. Since gain (dB) = 20 Log [R2/R1] we select an arbitrary value of R2 and then calculate R1. For this example we select R2 = 20K which yields an R1 of approximately 9.1K.

Receive from the Telephone Line

In a similar manner to the transmit calculation, we obtain the receive insertion loss from the data sheet and note that it is approximately 7dB. For an overall DAA gain on 1, it is necessary to select resistor values R5 and R6 such that 7dB amplification is achieved. Assuming R6 is 20K, R5 is calculated to be 44K.



NOTES:
Adjust R4 for maximum trans-hybrid loss from VT to VR. This circuit provides approximately -20dB loss.

R2/R1 provides +7dB amplification to compensate for -7dB transmit insertion loss in circuit.

R5/R6 provides +7dB amplification to compensate for -7dB receive insertion loss in circuit.

R3/C3 provides optimum return loss for nominal 600Ω line termination.

Figure 5. Hybrid Circuit

Receive and Transmit Signal Separation – Trans-hybrid loss

We now have the transmit and receive gains of U1A and U1B set such that VR will be at the same signal level as the incoming receive signal appearing on the Tip and Ring connections. Also, the Tip and Ring connections will see the same level transmit signal as VT. We must now attenuate the signal transmitted by the host system at VT to keep it from entering the receive path at VR, thus providing receive and transmit separation and completing the 2-4 wire converter. U1B is configured as a summing amplifier that sums the transmit VT signal with the transmit signal appearing at the LINE1 input of the CYG. These signals are 180° out of phase, therefore the resultant output of U1B will be 0V, thus removing the transmit signal from VR. Completely removing VT from VR would represent an infinite trans-hybrid loss. In practical circuits, it is not possible to achieve infinite loss. Losses can range from -10dB to -40dB depending on how well the components are matched and the impedance of the telephone line. Since the telephone line is a complex impedance, trans-hybrid loss also varies over the 300Hz - 4kHz voice band as shown in figure 6. R4 should be optimized to achieve the highest return loss possible with a 600Ω termination as shown in figure 7. R7 and C1 comprise a network suggested by the FCC to emulate the typical telephone line impedance.

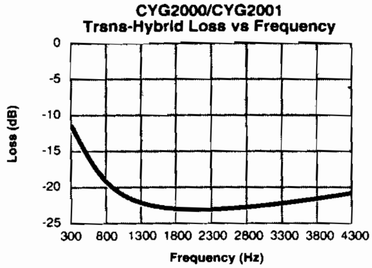
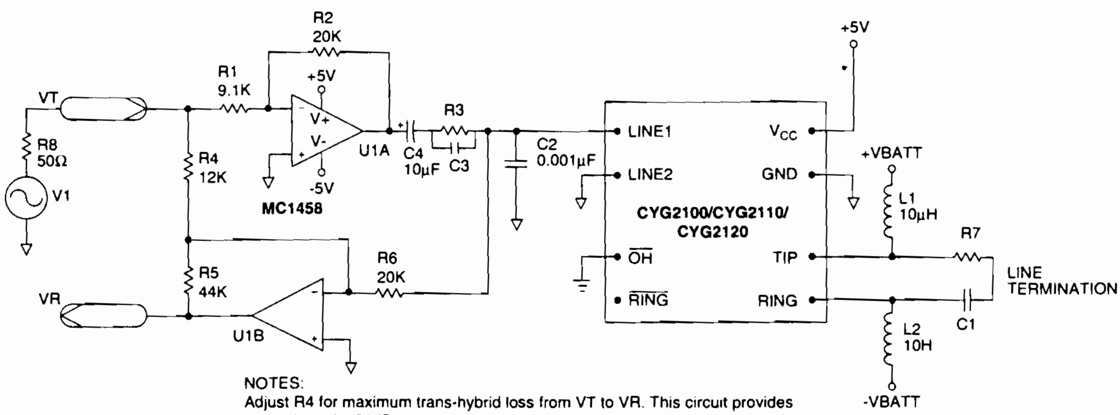


Figure 6. CYG2000/CYG2001 Trans-Hybrid Loss

Telephone line character varies from location to location in actual applications, and the 600Ω + 2.2µF combination should serve as a reference. C2 serves to improve the trans-hybrid loss by counteracting the leakage inductance of the transformer at higher frequencies. Referring to figure 6, the return loss maxima occur at the center of the voice band which is desirable for optimum operation.

Precautions When Implementing the Hybrid Circuit

Due to the small size and low distortion characteristics of the CYG's transformer, it is extremely important to



NOTES:
Adjust R4 for maximum trans-hybrid loss from VT to VR. This circuit provides approximately -20dB loss.

R2/R1 provides +7dB amplification to compensate for -7dB transmit insertion loss in circuit.

R5/R6 provides +7dB amplification to compensate for -7dB receive insertion loss in circuit.

R3 at 294Ω provides optimum return loss for nominal 600Ω line termination.

Figure 7. Addition of C2 DC Blocking Capacitor

use op amps with a low DC output offset voltage. Generally, any DC voltage exceeding 10mV on the output of U1A can cause the transformer's distortion characteristics to degrade due to core saturation. For op amps with higher output offset, it is advisable to use a 10μF capacitor (aluminum or tantalum) in series with R3 as shown in figure 7. This capacitor will block any DC offset voltage thus maintaining the transformer secondary DC current at 0mA. Op amps such as the MC1458 were found not to require this capacitor due to their offset being sufficiently low. The voltage rating of the capacitor should be rated 50VDC.

Return Loss Performance

The return loss is the measure of impedance mismatch of the telephone line and the DAA expressed in dB. Return loss is expressed as:

$$RL(dB) = 20 \text{ Log } \frac{[Z_L+Z_0]}{[Z_L-Z_0]}$$

where:

Z_L = Telephone line impedance in Ω

Z_0 = DAA impedance in Ω

If $Z_L = Z_0$ then the return loss is infinity which is the ideal case. As in the trans-hybrid loss case however, practical return loss figures are much lower than infinity and more like -25dB. Since impedance changes with frequency, the return loss also changes. A graph of return loss vs. frequency for the CYG is shown in figure 8. This graph was generated with the CYG terminated by a 600Ω + 2.16μF combination across Tip and Ring connections. Referring to figure 7, the key component determining the return loss match is the 294Ω resistor (R3) feeding the CYG's transformer secondary. This resistor value was selected for optimum return loss when used with the CYG and should not deviate in value by more than 5%.

Frequency Response

The CYG's frequency response is fairly flat with a deviation of ±0.2 dB. Its frequency response is shown in figure 9.

Regulatory Considerations

Interface to the Public Switched Telephone Network (PSTN)

The CYG2000/CYG2001 has been designed to comply with FCC Part 68.3 and DOC CS-03 requirements for connection to the public switched telephone network (PSTN). It is required however, that the designer submit the end product to a test lab to receive certification from the appropriate regulatory agency. The CYG2000/CYG2001 requires two external 10Ω 1/8W metal film resistors or one 1/4A fuse to meet the metallic surge requirement referred to in FCC part 68.302(d). This resistor/fuse will open if an 800V surge appears across the telephone line, thus preventing the CYG2000/CYG2001 from asserting a permanent off-hook condition to the telephone line in the event of a lightning strike or other induced surge. The.resistor is shown in figure 10.

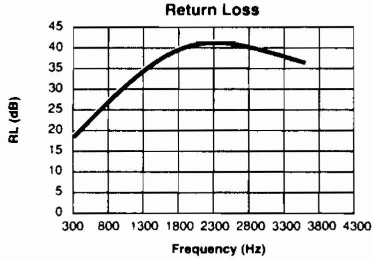


Figure 8. Return Loss

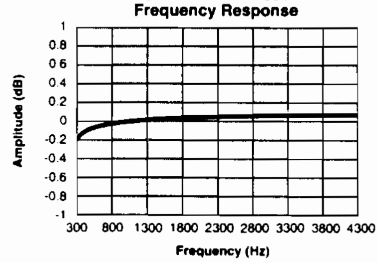


Figure 9. Frequency Response

EMI Considerations (FCC Part 15A/B)

The CYG2000/CYG2001 is a fully recognized component for both UL1459 and UL1950. When designing to UL1459, it is necessary to use a 1/4A 250V fuse in either the Tip or Ring line before the connection to the Cybergate™ in order for the recognition to remain valid.

Most commercial equipment are required to meet FCC part 15A or 15B which regulates Electromagnetic Interference (EMI). High speed modems and other circuits that contain high frequency crystal oscillators can present special problems when it comes time to submit the device to the FCC compliance lab. In order to minimize the risks associated with radiated emissions, the designer should keep the following points in mind:

- If possible, use a four-layer PCB design instead of a double-sided PCB. Having a separate V_{CC} and ground plane will minimize radiated emissions and decrease the noise susceptibility of the device. An alternative is to do a double-sided board and four-layer board in parallel and evaluate the results.
- Include a provision on your PCB design for a 1/2 turn ferrite bead and capacitor in your layout from the Tip and Ring terminals of the DAA to the telephone jack as shown in figure 11. This LC network will form a low pass filter that will roll off high frequencies. The decision to populate the board with these components will be based on the results of the radiated emissions coming out of the telephone line during FCC testing.
- If a multi-layer board is not used, keep ground traces at least 25 mils to 50 mils wide.
- Maintain LINE1 and LINE2 connections as short as possible and use guarding techniques when running these traces.
- Maintain Tip and Ring connections at least 100 mils away from all other connections on the boards. If a ground plane is used, keep the plane away from Tip and Ring connections.

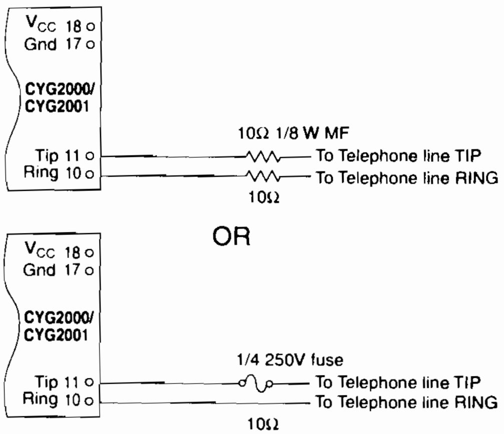


Figure 10. Fuse Requirements

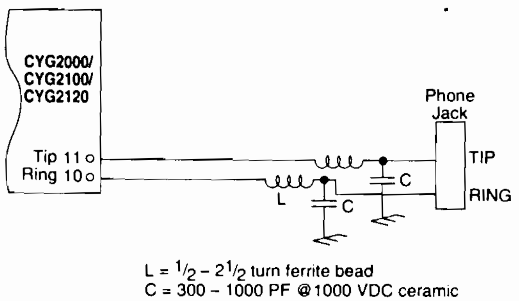


Figure 11. EMI Considerations